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**Small solid oxide fuel cell power
systems—Part 3: Performance
testing methods and environment
testing methods**

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Foreword

This translation has been made based on the original Japanese Industrial Standard established by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee according to the proposal for establishment of Japanese Industrial Standard submitted by the Japan Electrical Manufacturers' Association (JEMA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law.

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JIS C 8841 series consists of the following 3 parts under the general title "*Small solid oxide fuel cell power systems*".

Part 1: General rules

Part 2: General safety codes and safety testing methods

Part 3: Performance testing methods and environment testing methods

Small solid oxide fuel cell power systems— Part 3: Performance testing methods and environment testing methods

1 Scope

This Japanese Industrial Standard specifies the performance testing methods and environment testing methods of the stationary small solid oxide fuel cell power systems (hereafter referred to as “fuel cell systems”) which are in accordance with the following a) to h).

- a) **Type of fuel cell** Solid oxide fuel cell
- b) **Output** Rated power transmission output of less than 10 kW
- c) **Output mode** DC output, AC output or both outputs of DC output and AC output
- d) **Output voltage** 220 V or less in the case of AC output
- e) **Operation mode** Grid-connected operation, grid-independent operation or independent operation
- f) **Raw fuel** Gaseous fuel (city gas, liquefied petroleum gas, etc.), liquid fuel (kerosene, etc.) or hydrogen
- g) **Operating pressure** Maximum working pressure of the section where fuel gas flows shall be less than 0.1 MPa. That of the section where liquid gas flows shall be less than 1.0 MPa.
- h) **System configuration** Stationary power generation dedicated system or cogeneration system stored in a package

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS B 7951 *Continuous analyzer for carbon monoxide in ambient air*

JIS B 7956 *Continuous analyzers for hydrocarbons in ambient air*

JIS B 7981 *Automated measuring systems and analyzers for sulfur dioxide in flue gas*

JIS B 7982 *Automated measuring systems and analyzers for nitrogen oxides in flue gas*

JIS B 7983 *Continuous analyzers for oxygen in flue gas*

JIS C 8800 *Glossary of terms for fuel cell power system*

JIS C 8841-1 *Small solid oxide fuel cell power systems—Part 1: General rules*

- JIS D 1030 *Automobiles—Analytical procedure for measurement of carbon monoxide, carbon dioxide, total hydrocarbons and oxides of nitrogen in exhaust gas*
- JIS K 0098 *Methods for determination of carbon monoxide in flue gas*
- JIS K 0102 *Testing methods for industrial wastewater*
- JIS K 0103 *Methods for determination of sulfur oxides in flue gas*
- JIS K 0104 *Methods for determination of nitrogen oxides in flue gas*
- JIS K 0301 *Methods for determination of oxygen in flue gas*
- JIS K 0304 *Methods for determination of carbon dioxide in air*
- JIS K 2240 *Liquefied petroleum gases*
- JIS K 2249 *Crude petroleum and petroleum products—Determination of density and petroleum measurement tables based on a reference temperature (15 °C)*

3 Terms and definitions

For the purpose of this Standard, the terms and definitions given in **JIS C 8800**, **JIS C 8841-1** and the following apply.

3.1 load change

automatic change to an ordered value of the output electric power of a power generation unit together with a certain load change order

4 Configuration and scope

The basic configuration of the fuel cell system shall be as specified in clause 4 of **JIS C 8841-1**.

5 Operation process

The typical operation process of a power generation unit shall be as specified in clause 10 of **JIS C 8841-1**.

6 Measurement items, measurement positions and measuring instrument

The measurement items and measurement positions shall be as specified in clause 12 of **JIS C 8841-1**. The measuring instrument shall be as specified in clause 13 of **JIS C 8841-1**.

7 Conditions concerning test

The conditions concerning test shall be as specified in clause 14 of **JIS C 8841-1**.

8 Reference and calculation of heating value

The reference and calculation of heating value shall be as specified in clause 15 of **JIS C 8841-1**.

9 Performance test

9.1 Fuel consumption heating value test

9.1.1 Gaseous fuel consumption heating value test

The gaseous fuel consumption heating value test shall be as follows.

- a) **Purpose of test** This test is performed to measure the heating value of gaseous fuel consumption of a power generation unit.
- b) **Measurement items** As specified in table 1 and clause 6.

Table 1 Measurement items

Measurement item	Symbol	Unit	Measuring instrument	Sampling period
Actually measured fuel consumption	V_f	m^3	Flowmeter or integrating flowmeter	—
Raw fuel temperature	T_f	$^{\circ}\text{C}$	Thermometer	Average during measuring time (t)
Raw fuel pressure (gauge pressure)	p_f	kPa	Gauge pressure meter	
Atmospheric pressure (absolute pressure)	$p_{0\text{ave}}$	kPa	Barometer	
Measuring time	t	h	Stopwatch	At the time of test start and test end

- c) **Test condition** As specified in clause 7.
- d) **Test method** The test method shall be as follows.
 - 1) Start the test from the state in which the power generation unit has been operated for at least 30 min at the rated output.
 - 2) The measuring time (t) shall be 3 h or more. However, when fuel is intermittently supplied, the measuring time shall be either 20 times the fuel supply intervals or 3 h, whichever is longer.
 - 3) For the actually measured fuel consumption (V_f), measure the fuel consumption during measuring time (t).
- e) **Calculation of results** Calculate the integrating fuel consumption heating value (Q_f) and fuel consumption heating value per unit time (I_f) that are converted into a temperature of 15 $^{\circ}\text{C}$ and an atmospheric pressure (absolute pressure) of 101.3 kPa according to formula (1) to formula (3). For raw fuel temperature (T_f), raw fuel pressure (gauge pressure) (p_f) and atmospheric pressure (absolute pressure) ($p_{0\text{ave}}$), use the average during the measuring time (t), respectively. Obtain the fuel heating value per unit volume of gaseous fuel (H_G) in accordance with **15.2** of **JIS C 8841-1**.

1) **Fuel consumption converted into temperature of 15 °C and atmospheric pressure (absolute pressure) of 101.3 kPa**

$$V_{f0} = V_f \times \frac{288.2}{273.2 + T_f} \times \frac{p_f + p_{0ave}}{101.3} \dots\dots\dots (1)$$

where, V_{f0} : fuel consumption converted into a temperature of 15 °C and atmospheric pressure (absolute pressure) of 101.3 kPa (m³)

V_f : actually measured fuel consumption (m³)

T_f : raw fuel temperature (°C)

p_f : raw fuel pressure (gauge pressure) (kPa)

p_{0ave} : atmospheric pressure (absolute pressure) (kPa)

2) **Integrating fuel consumption**

$$Q_f = V_{f0} \times H_G \dots\dots\dots (2)$$

where, Q_f : integrating fuel consumption (kWh)

V_{f0} : fuel consumption converted into a temperature of 15 °C and atmospheric pressure (absolute pressure) of 101.3 kPa (m³)

H_G : fuel heating value per unit volume of gaseous fuel (kWh/m³)

3) **Fuel consumption heating value per unit time**

$$I_f = \frac{Q_f}{t} \dots\dots\dots (3)$$

where, I_f : fuel consumption heating value per unit time (kW)

Q_f : integrating fuel consumption heating value (kWh)

t : measuring time (h)

f) **Record of results** An example of the test result table is given in table A.1.

9.1.2 Liquid fuel consumption heating value test

The liquid fuel consumption heating value test shall be as follows.

a) **Purpose of test** This test is performed to measure the heating value of liquid fuel consumption of a power generation unit.

b) **Measurement items** As specified in table 2 and clause 6.

Table 2 Measurement items

Measurement item	Symbol	Unit	Measuring instrument	Sampling period
Mass of fuel tank at the test start	W_{t1}	kg	Mass spectrometer	At the test start
Mass of fuel tank at the test end	W_{t2}	kg		At the test end
Mass of residual fuel at the test start	W_{b1}	kg		At the test start
Mass of residual fuel at the test end	W_{b2}	kg		At the test end
Actually measured fuel consumption	V_f	m ³	Flowmeter or integrating flowmeter	—
Fuel density	ρ_f	kg/m ³	Densitometer	—
Measuring time	t	h	Stopwatch	At the test start and test end

c) **Test condition** As specified in clause 7.

d) **Test method** The test method shall be as follows.

- 1) Start the test from the state in which the power generation unit has been operated for at least 30 min at the rated output.
- 2) The measuring time (t) shall be 3 h or more. However, when fuel is intermittently supplied, the measuring time shall be either 20 times the fuel supply intervals or 3 h, whichever is longer.
- 3) Measure the mass of the fuel tank at the test start and test end (W_{t1} and W_{t2}). When it is difficult to measure the mass, attach a flowmeter or an integrating flowmeter to the fuel tank outlet, and measure the actually measured fuel consumption (V_f).
- 4) When fuel is intermittently supplied, measure the mass of the residual fuel inside the fuel cell system at the test start and test end (W_{b1} and W_{b2}). When it is difficult to measure the mass, attach a flowmeter or an integrating flowmeter to the buffer tank outlet in the system and hot-water storage tank fuel supplying line, and measure the integrating flow rate of each, and measure the combined actually measured fuel consumption (V_f).

e) **Calculation of results** Calculate the integrating fuel consumption heating value (Q_f) and fuel consumption heating value per unit time (I_f) according to formula (4) to formula (7). Obtain the fuel heating value per unit mass of liquid fuel (H_L) in accordance with 15.2 of JIS C 8841-1.

- 1) **Integrating fuel consumption heating value** When using an integrating flowmeter, it shall be calculated according to formula (4) or formula (5).

$$Q_f = (W_{t1} - W_{t2}) \times \frac{H_L}{3.6} \dots\dots\dots (4)$$

where, Q_f : integrating fuel consumption heating value (kWh)

W_{t1} : mass of fuel tank at the test start (kg)

W_{t2} : mass of fuel tank at the test end (kg)

H_L : fuel heating value per unit mass of liquid fuel (MJ/kg)

$$Q_f = (W_{t1} - W_{t2} + W_{b1} - W_{b2}) \times \frac{H_L}{3.6} \dots\dots\dots (5)$$

where, Q_f : integrating fuel consumption heating value (kWh)
 W_{t1} : mass of fuel tank at the test start (kg)
 W_{t2} : mass of fuel tank at the test end (kg)
 W_{b1} : residual fuel mass in the fuel cell system at the test start (kg)
 W_{b2} : residual fuel mass in the fuel cell system at the test end (kg)
 H_L : fuel heating value per unit mass of liquid fuel (MJ/kg)

When using a flowmeter, it shall be calculated according to formula (6)

$$Q_f = V_f \times \rho_f \times \frac{H_L}{3.6} \dots\dots\dots (6)$$

where, Q_f : integrating fuel consumption heating value (kWh)
 V_f : actually measured fuel consumption (m³)
 ρ_f : fuel density (kg/m³)
 H_L : fuel heating value per unit mass of liquid fuel (MJ/kg)

2) Fuel consumption heating value per unit time

$$I_f = \frac{Q_f}{t} \dots\dots\dots (7)$$

where, I_f : fuel consumption heating value per unit time (kW)
 Q_f : integrating fuel consumption heating value (kWh)
 t : measuring time (h)

f) **Record of results** An example of the test result table is given in table A.2.

9.2 Startup test

The startup test shall be as follows.

- a) **Purpose of test** This test is performed to measure the startup time of a power generation unit, the energy needed for starting up and the received electric power in a storage state.
- b) **Measurement items** As specified in table 3 and clause 6. The measurement item required for calculation of an integrating fuel consumption heating value shall be as specified in 9.1.

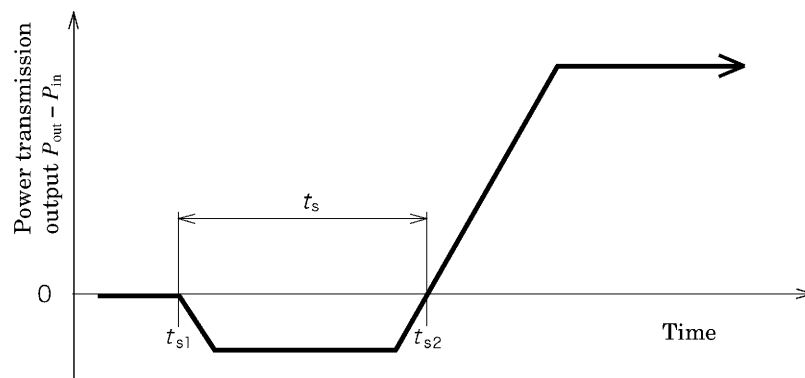
Table 3 Measurement items

Measurement item	Symbol	Unit	Measuring instrument	Sampling period
Transmitted electric power	P_{out}	kW	Wattmeter	15 s max.
Received electric power	P_{in}	kW		
Transmitted electric energy	W_{out}	kWh	Watthour meter or integrating wattmeter	
Received electric energy	W_{in}	kWh		
Startup operation start time	t_{s1}	h : min	Clock	At the start of startup operation
Startup operation completion time	t_{s2}	h : min		At the completion of startup operation
Measuring time	t	h	Stopwatch	At the test start and test end

c) **Test condition** As specified in clause 7.

d) **Test method** The test method shall be as follows.

- 1) Start the test from the cold state, the storage state or the state in which at least 48 h has elapsed from the previous operation stop time.
- 2) Measure the transmitted electric power (P_{out}), received electric power (P_{in}), transmitted electric energy (W_{out}) and received electric energy (W_{in}).
- 3) Start the startup operation and record the startup operation start time (t_{s1}).
- 4) As shown in figure 1, record the startup operation completion time (time when $P_{\text{out}} - P_{\text{in}} > 0$) (t_{s2}).
- 5) Perform measurement of the measurement items required for calculation of the integrating fuel consumption heating value for the time (t_s) from the startup operation start time (t_{s1}) up to the startup operation completion time (t_{s2}) in accordance with 9.1.
- 6) Confirm that the power generation unit is in a storage state, and measure the received power energy (W_{in}) during the measuring time (t). The measuring time (t) shall be 3 h or more.

**Figure 1 Startup time relation diagram**

e) **Calculation of results** The calculation of results shall be as follows.

1) **Startup time** Calculate according to formula (8).

$$t_s = t_{s2} - t_{s1} \dots\dots\dots (8)$$

where, t_s : startup period (min)
 t_{s2} : startup operation completion time (h : min)
 t_{s1} : startup operation start time (h : min)

2) **Startup energy** The startup energy shall be as follows.

2.1) **Startup energy (fuel)** Obtain the integrating fuel consumption heating value in startup time (t_s) in accordance with **9.1.1** or **9.1.2**, and take it as startup energy (fuel) (E_{sf}).

2.2) **Startup energy (electric power)** Calculate according to formula (9).

$$E_{se} = W_{in} - W_{out} \dots\dots\dots (9)$$

where, E_{se} : startup energy (electric power) (kWh)
 W_{in} : received electric energy from startup operation start to completion (kWh)
 W_{out} : transmitted electric energy from startup operation start to completion (kWh)

2.3) **Startup energy** Calculate according to formula (10).

$$E_s = E_{sf} + E_{se} \dots\dots\dots (10)$$

where, E_s : startup energy (kWh)
 E_{sf} : startup energy (fuel) (kWh)
 E_{se} : startup energy (electric power) (kWh)

2.4) **Received electric power in storage state** Calculate according to formula (11).

$$P_{inst} = \frac{W_{in}}{t} \dots\dots\dots (11)$$

where, P_{inst} : received electric power in storage state (kW)
 W_{in} : received electric energy (kWh)
 t : measuring time (h)

f) **Record of results** An example of the record table of test results is given in table A.3.

9.3 Electric output test

The electric output test shall be as follows.

- a) **Purpose of test** This test is performed to measure the electric generating power of a power generation unit.
- b) **Measurement items** As specified in table 4 and clause 6.

Table 4 Measurement items

Measurement item	Symbol	Unit	Measuring instrument	Sampling period
Transmitted electric energy	W_{out}	kWh	Watt-hour meter or integrating wattmeter	60 s max.
Received electric energy	W_{in}	kWh		
Measuring time	t	h	Stopwatch	At the test start and test end

- c) **Test condition** As specified in clause 7.
- d) **Test method** The test method shall be as follows.
- 1) Start the test from the state in which the power generating unit has been operated for at least 30 min at the power transmission output specified beforehand. The power transmission output specified beforehand refers to a rated output (75 % output, 50 % output, minimum output or output equivalent to these, as necessary).
 - 2) The measuring time (t) shall be 3 h or more.
 - 3) Measure the transmitted electric energy (W_{out}) and received electric energy (W_{in}). When the electric power for auxiliary equipment power is not received, the measurement of received electric energy may be omitted.
- e) **Calculation of results** The calculation of results shall be as follows.
- 1) **Power transmission output** Calculate according to formula (12). When the electric power for auxiliary equipment power is not received, treat the received electric energy as zero.
- $$P = \frac{W_{\text{out}} - W_{\text{in}}}{t} \dots\dots\dots (12)$$
- where, P : power transmission output (kW)
 W_{out} : transmitted electric energy (kWh)
 W_{in} : received electric energy (kWh)
 t : measuring time (h)
- f) **Record of results** An example of the record table of test results is given in table A.4.

9.4 Efficiency test

9.4.1 Electrical efficiency test

The electrical efficiency test shall be as follows.

- Purpose of test** This test is performed to measure the electrical efficiency of a power generation unit.
- Measurement items** As specified in table 5 and clause 6. The measurement items required for calculation of integrating fuel consumption heating value shall be as specified in 9.1.